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Original Communication

Age estimation from pulp/tooth area ratio in maxillary incisors among Egyptians using dental radiographic images

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ABSTRACT

Age estimation from dental radiographs is a non-destructive, simple method to obtain information. The aim of this study was to determine the reliability of age estimation from Egyptians' incisors radiographs. 144 periapical radiographs of maxillary (central & lateral) incisors (both sexes) aged 12–60 were used. Digital camera was used to image the radiographs. Images were computed and pulp/tooth area ratios were determined by AutoCAD Program. Data were subjected to correlation and regression analysis which showed statistically significant correlation ($r = 0.23$ & $P = 0.006$ for maxillary central incisors and $r = -0.2$ & $P = 0.05$ for maxillary lateral incisors) between age and pulp tooth area ratio. Linear regression equations were determined separately for both central and lateral incisors along with the corresponding Standard Error of Estimate, which ranged from 1.2 to 5.08 years. Consequently, it was concluded that pulp/tooth area ratios of incisors are reliable for estimation of age among Egyptians in forensic work.

1. Introduction

Estimation of age in individuals has received a considerable attention in forensic science, in which it is a widely used method for individual identification.[1]

Teeth are useful as biological markers for human age estimation because they may be preserved for long time after death.[2]

Dental age prediction in adults is usually accomplished using a number of methods, most notably being Gustafson's parameters[3] and Johanson's grading,[4] dental translucency[5] and cementum annulations.[6] Other studies based on amino acid racemization[7] and dental nuclear tests.[8] These methods which most frequently used require extraction, and some of them preparation of microscopic sections of at least one tooth. These methods are time-consuming, expensive and a destructive approach may not be acceptable for ethical, religious, cultural or scientific reasons.[9]

Kvaal et al., 1995,[10] introduced a method which depends on measurements of secondary dentine deposition on radiographs by measuring pulp translucency and correlated it to age. Subsequently, age estimation based on radiographic measurements of teeth has been reported in many studies and is most commonly used to determine age in living humans.[11]

Cameriere et al.,[9,12,13] estimated age by measurements of tooth pulp areas ratios for different types of teeth. Since recent reports advocate constructing population-specific equations[14] to enhance age prediction, this study was done to estimate age from pulp/tooth area ratio from Egyptian peri-apical dental radiographs.

2. Subjects and methods

A total of 144 peri-apical X-rays of maxillary central and lateral incisors were assembled from 64 males and 80 females aged between 12 and 60 years. They were taken from the Endodontic Department, Faculty of Dentistry, Minia University. All individuals were with well-known chronological age. The exclusion criteria were: impacted teeth, teeth with root canal treatment, teeth with large areas of enamel overlap between neighboring teeth, and teeth with vestibular radio-opaque fillings, crown or pathological processes visible on the radiograph. Protocol of the study was approved by Ethical committee of Faculty of Medicine, Minia University.

Peri-apical X-rays were taken using X-ray equipment, Kv70, MA 8, ORI X 70 with manual processing which made in Italy. According

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to Kolveit et al., 1998,[15] each radiograph was mounted on X-ray illuminating table and viewed through a digital camera (Sony DSC-W80, 7.2 megapexil). Then the radiographic images were converted to a portable Pc. Following Cameriere et al., 2009,[16] the X-ray images were photo edited, twenty points from each tooth outline and 10 for each pulp outline were identified. These points used to evaluate both tooth and pulp areas by AutoCAD (2008) program for both maxillary central & lateral incisors (Fig. 1). Based on these measurements, the area ratios of the pulp to the whole tooth were obtained.

All measurements were carried out by the same examiner. To test intra-examiner reproducibility, a random sample of 30 digital X-ray were re-examined after an interval of two weeks. Intra-examiner reproducibility of measurements was determined by paired *t*-test, according to Aboshi et al., 2010.[17]

Periapical digital X-rays were classified into 5 age groups: group I (12–20 years), group II (21–30 years), group III (31–40 years), group IV (41–50 years) and group V (51–60 years).

Kvaal et al., 1995, stated that there were no significant differences between permanent teeth from the left and right side of the jaw. Consequently, in the present study teeth were chosen either from the left or the right side, whichever were best suited for measurement.

3. Statistical analysis

Statistical analysis was performed using Statistical Program for Social Sciences (SPSS), Version 11 (IBM Company, Chicago, IL). Karl Pearson's correlation coefficient was calculated to determine the association between age and PT ratios as well as analysis of covariance (ANCOVA) to study the possible interaction between age & sex and maxillary central & lateral incisors. Linear regression equations were performed to calculate the regression equations following Cameriere et al., 2009.[16] Regression equations were also computed for estimating age. The standard error of estimate (SEE) was calculated to predict the deviation of the estimated age from the actual .The significance of the difference between chronological and dental age and intra-examiner reproducibility were tested by paired Student *t*-test.

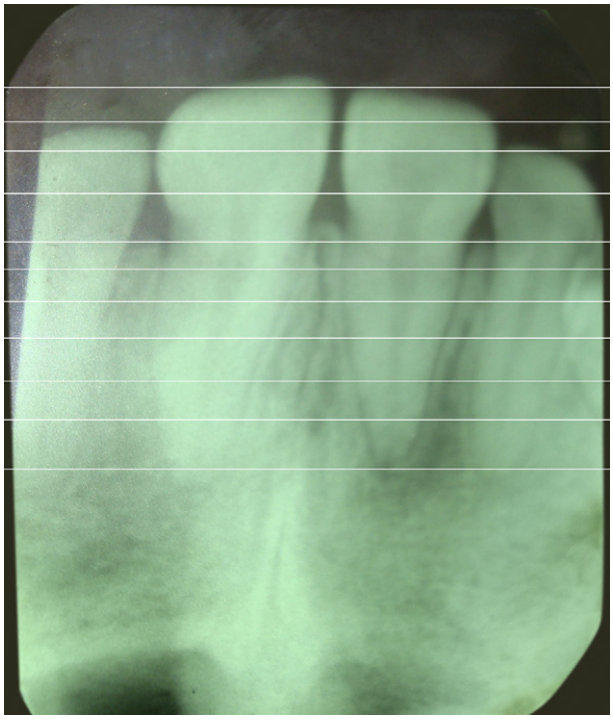

Fig. 1. The tooth's long axis is aligned vertically and horizontal lines drawn on the crown and root using Adobe Photoshop. Using AutoCAD, points were marked at the junction of these lines and the perimeters of the tooth and pulp.

Table 1
Showing age and gender distribution of dental radiographs among the studied Egyptian sample.

Age category (years)	No. of males	No. of females	Total
Group I (12–20)	16	22	38
Group II (21–30)	8	22	30
Group III (31–40)	20	10	30
Group IV (41–50)	4	18	22
Group V (51–60)	16	8	24
Total	64	80	144

4. Results

There were no statistical significant intra-examiner differences between the paired sets of measurements carried out on the re-examined data ($t = 0.52$, $p = 0.6$ for central incisors & $t = 0.82$, $p = 0.4$ for lateral incisors).

Age and sex distribution of individuals are presented in Tables 1 and 2. The descriptive statistics for different age groups, for pulp tooth ratios of maxillary central and lateral incisors were shown in Table 3.

Pearson's correlation for the Egyptian sample produced a statistically significant correlation between pulp/tooth area ratio and chronological age ($r = -0.23$ & $P = 0.006$ for maxillary central incisors and $r = -0.2$ & $P = 0.05$ for maxillary lateral incisors).

ANCOVA analysis showed that sex did not contribute significantly to pulp/tooth ratio ($F = 0.79$, $p = 0.74$ for central incisors and $F = 0.74$, $p = 0.77$ for lateral incisors), however age significantly influenced pulp tooth ratio ($F = 3.42$ and $p = 0.000$ for central and $F = 2.04$ and $p = 0.003$ for lateral) which can be used to estimate chronological age for both in different age groups from 12 to 60 years.

Linear regression analysis, where age was the dependent variable and pulp/tooth ratios was the independent variables, showed a coefficient of determination ($R^2 = 0.1$ for maxillary central incisor teeth and 0.02 for maxillary lateral incisor teeth).

Linear regression equations for estimation of age from pulp/tooth areas ratios were presented in Table 4. Regression equations have been computed separately for each age group and for central and lateral incisors. The table also exhibits standard error of estimate (SEE) along with every linear regression equation.

The SEE predicts the deviation of estimated age from calculated age (actual age). A low value indicates greater reliability in the estimated age. SEE ranged from 1.36 to 5.08 years for age estimation from central incisors and from 1.2 to 2.70 for age estimation from lateral incisors. Lateral incisors are better for all age groups except age group I (Table 4).

Regression analysis was shown in Table 5 predicting age from maxillary central ($P = 0.006$) and lateral ($P = 0.05$) incisors.

Table 2
Descriptive statistics for the chronological age of the Egyptian sample.

Ages (years)	Min.	Max.	Mean	SD	No
Group I (12–20)	13	20	17.42	2.79	38
Group II (21–30)	21	29	24.86	2.19	30
Group III (31–40)	33	40	37.20	2.52	30
Group IV (41–50)	43	50	47.18	2.53	22
Group V (51–60)	51	60	56.66	3.61	24

Min.: Minimum, Max.: Maximum, SD: Standard deviation, No: Number, C: Central incisor, L: Lateral incisor.

Table 3
Descriptive statistics of pulp/tooth ratios of central and lateral maxillary incisors of Egyptian sample.

		Min.	Max.	Mean	±SD	No
Group 1	C	0.02	0.33	0.177	0.06	38
	L	0.12	0.34	0.195	0.05	38
Group II	C	0.10	0.35	0.193	0.07	30
	L	0.06	0.50	0.189	0.10	30
Group III	C	0.02	0.38	0.127	0.08	30
	L	0.07	0.30	0.152	0.05	30
Group IV	C	0.01	0.45	0.169	0.10	22
	L	0.02	0.20	0.142	0.05	22
Group V	C	0.06	0.29	0.139	0.06	24
	L	0.05	0.30	0.182	0.08	24

Min.: Minimum, Max.: Maximum, SD: Standard deviation, No: Number, C: Central incisors, L: Lateral incisors.

Table 6 showed the descriptive statistics for the estimated ages in the different age groups. The estimated ages were very close to the chronological age with insignificant difference in between ($P > 0.05$) (Table 7).

5. Discussion

The study of morphological parameters of the teeth on radiographs is considered to be more reliable than most other methods of age estimation.[12]

Assessment of pulp/tooth area ratio, in particular, is an indirect quantification of secondary dentine deposition.[17] Secondary dentine has been preferred since it is encased not only by harder tissue such as enamel and cementum, but also by primary dentine.[9] Consequently, evaluation of this parameter is considered as an "internal examination", with the potential to eliminate the effect of environmental factors on human remains.[11]

In addition, earlier studies have indicated that the amount of secondary dentine is correlated with chronological age[4,19,20] and can be measured indirectly by radiographs.[10,21–23]

The ratio between the tooth and pulp measurements was calculated and used in the analysis of this study, in order to reduce the effect of a possible variation in the magnification and angulations of the radiographs.[10]

In this study, Maxillary teeth were used as they are more convenient for age determination than mandibular as Brkic et al., 2006, found that teeth of both jaws are reliable for the dental age estimation, but the correlation coefficient was stronger for all of the types of teeth in the upper jaw.[24] In addition, Fancy et al., 1980,[25] stated that growth layers of maxillary teeth are more regular and distinct than those of mandibular teeth.

The aim of this work was to attempt establishing a correlation between the chronological age of Egyptian individuals (12–60 years males and females) and the Pulp/tooth ratio of maxillary incisors.

Table 4
Showing the Linear regression equations for Egyptian individuals (no. 144).

Groups		Linear regression equation	±SEE
Group I	C	21.07 − 20.55 × Ratio IC	1.75
	L	21.12 − 18.97 × Ratio IL	2.02
Group II	C	24.26 + 3.11 × Ratio IIC	1.36
	L	24.51 + 1.84 × Ratio IIL	1.2
Group III	C	39.00 − 14.22 × Ratio IIIC	1.73
	L	35.77 + 9.38 × Ratio IIIL	1.67
Group IV	C	47.32 − 0.86 × Ratio IVC	2.36
	L	48.79 − 11.28 × Ratio IVL	2.13
Group V	C	56.95 − 2.07 × Ratio VC	5.08
	L	55.11 + 8.51 × Ratio VL	2.70

SEE: Standard error of estimate.

Table 5
Regression analysis predicting age from central & lateral maxillary incisors for Egyptian sample.

	Value	St. error	*t*-value	*P*
Constant	40.76	2.65	15.33	0.000*
Central incisor	−40.46	14.61	−2.77	0.006*
Constant	39.30	3.04	12.89	0.000*
Lateral incisor	−29.29	16.61	−1.83	0.05*

St. error: Standard error, *P*: Significance, *: Significance ≤ 0.05.

A statistically significant correlation between Egyptian sample aged 12 to 60 years and pulp/tooth area ratio, was found in this study ($r = 0.23, p = 0.006$ and $r = 0.2, p = 0.05$ for central and lateral incisors respectively). These results are in agreement with Bosmans et al., 2005,[26] who utilized radiographs of maxillary & mandibular incisors dimensions − of adult Belgian individuals − and found that all correlations were significant. Also, these results are inline with Yang et al., 2006[27] who reported moderate correlation between pulp/tooth volume ratio of incisors and biological age by using cone-beam CT for Belgian. In the other hand, Someda et al., 2009,[28] study on pulp/tooth volume ratios of Japanese mandibular incisors, revealed high correlations, who attributed accuracy of age estimation to the fact that mandibular central incisors have the lowest morphological diversity among human permanent teeth. Solheim, 1993[19] found a significant correlation between age and dimensions of maxillary central incisors among a sample of 1000 teeth, (r) was 0.91.

Similar to results of this study ($r = 0.23$ and 0.2 for central and lateral incisors respectively), Babshet et al., 2010,[18] who found low correlation for mandibular canines ($r = -0.34$ & $p < 0.001$) in 143 Indian individuals, they attributed this low correlation to the rate of secondary dentine deposition in canine teeth which doesn't progress consistently with an increase in age. In other words secondary dentinal deposition may be relatively slow and irregularly paced in their population (Indians). Our finding here point to the same inference as far as secondary dentine deposition is concerned.

This work revealed that correlation was negative and significant, this was meeting with Someda et al., 2009,[28] who stated that age-related formation of secondary dentin is directly related to decrease in pulp cavity volume.

As regards linear regression analysis for age estimation from incisors pulp/tooth area ratio, SEE was ranging from 1.2 to 3.08 years. There are paucity of literatures concerning incisors related to this matter, but studied on other teeth by Cameriere et al., 2009,[16] determined SEE about 2.5 years for age estimation from canine pulp/tooth area ratio. SEE < ±10 years is considered acceptable in forensic age prediction.[29]

Coefficient of determination (R^2) of this study was 0.1. Yang et al., 2006[27] found that coefficient of determination was 0.29% or 0.29 which is the proportion of the variation in age that can be

Table 6
Showing descriptive statistics for the estimated age from both central & lateral incisors in the Egyptian sample.

Area (years)		Min.	Max.	Mean	±SD
Group I (12–20)	C	14.29	20.66	17.41	1.42
	L	14.67	18.84	17.41	1.02
Group II (21–30)	C	24.57	25.35	24.86	0.22
	L	24.62	25.43	24.85	0.19
Group III (31–40)	C	33.60	38.74	37.19	1.14
	L	36.46	38.72	37.26	0.57
Group IV (41–50)	C	46.93	47.31	47.17	0.09
	L	46.53	84.56	47.18	0.60
Group V (51–60)	C	56.35	56.83	56.66	0.13
	L	55.12	57.66	56.66	0.71

C: Central incisor, L: Lateral incisor, Min.: minimum, Max.: maximum and SD: standard deviation.

Table 7
Paired *t*-test evaluating the comparison between the chronological and estimated ages in different age groups.

Groups	Chronological age	Estimated age	*t*-value	*P*
IC	17.42	17.41	0.017	0.98
IL	17.42	17.41	0.012	0.99
IIC	24.86	24.86	0.014	0.98
IIL	24.86	24.85	0.021	0.98
IIIC	37.20	37.19	0.021	0.98
IIIL	37.20	37.26	0.143	0.88
IVC	47.18	47.17	0.013	0.98
IVL	47.18	47.18	0.003	0.99
VC	56.66	56.66	0.702	0.25
VL	56.66	56.66	0.004	0.99

P: Significance (at $\leq$0.05).

accounted for by variation in ratio. A study done by Ubelaker & Parra, 2008,[14] revealed that correlation coefficients vary from 0.69 to 0.86 for single-rooted teeth (including maxillary and mandibular central incisors) from different regions of Peru.

No statistically sex influence on pulp/tooth area ratio by ANCOVA analysis, in this study. This was parallel to Cameriere et al., 2009,[16] who found no significant effect of sex on the regression models. Rai & Anand, 2008,[30] reported that by ANCOVA analysis, sex contributed significantly to the fit. This also can be explained by ethnic difference.[18]

This work revealed no significant difference between chronological and estimated ages. This was consistent to Bosmans et al., 2005,[26] who found no significant differences between chronological & calculated ages. As accuracy of age prediction is the closeness of estimated age to chronological age,[31] consequently, it was concluded that, this research showed promising results for dental age estimation in a non-invasive manner using dental radiographs from maxillary incisor teeth among Egyptian population. So, it is recommended that more population-specific equation must be made to reach maximum accuracy. The use of several teeth together and multiple regression analysis must be investigated in order to improve dental age estimation.

Conflict of interest

Estimation of age from tooth radiographs in Egyptians.

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Ethical approval

Protocol of the study was approved by Ethical Committee of Faculty of Medicine, Minia University.

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